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Industrial Pesticides and a Methods Assessment for the Reduction of Associated Risks: A Review

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Abstract

Regarding the increasing growth of the population and importance of food security, Iranian Ministry of Agriculture has prioritized and encouraged greenhouse farming products. One of the developmental challenges of greenhouse farming is the current extensive use of chemical fertilizers. Importantly, as raw agricultural products are the main ingredients on the table of Iranian families (Iranians generally tend to eat fresh products), the determination of pesticide residues in such products is of utmost importance. The penetration of resistant contaminants into freshwater resources can lead to detrimental effects on humans and the environment. Concerning the importance of environmental protection and the role of chemical pesticides, this study reviews the pesticides used in the agronomic sector and the associated risks of using chemicals to control pests for society, agriculture, freshwater resources, and the environment.

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Introduction

Increased population and the increasing need for food production have resulted in the expansion of compact agriculture and pesticides for fighting pests and insects to maximize quantity and quality. Water stress is one of the most limiting factors around the world [1-4]. After application, pesticides can percolate into groundwater in the form of leachate, reach the surface waters through the runoff, or remain in agricultural products as residues, enter the food industry and end up in the hands of consumers, putting the health of individuals at risk [5-7]. The results of relevant studies indicate that pesticides formerly originated in materials collected from plants, animals, and of course, chemicals. The use of specific amounts of such materials could lead to temporary or permanent malfunction or dysfunction of vital mechanisms [8, 9]. Chemical pesticides are generally divided into four families of poisons: organochlorides, organophosphates, carbamates, and pyrethroid**s.** Organophosphorus compounds are significantly diverse, securing a 40% share of the market [10].

Due to the lipophilicity, bio-accumulation factor (BAF), and the presence in the food chain, organophosphorus pesticides (OPs) are critical compounds for the significant impacts they have on society's health and the environment. Various research attempts have focused on the toxic effects of this pesticide on the environment [11, 12]. WHO has labeled this pesticide moderately hazardous under class II. Coumaphos is a principal insecticide in the organophosphate family of pesticides, used in industries related to animal breeding such as in aviculture, beekeeping, cattle tick elimination, and other external parasites [13-15].

Atrazine is an herbicide widely used on farms in Iran, causing pollution in various ecosystems due to its low vapor pressure (LVP), the long half-life, and significant mobility. U.S. Environmental Protection Agency classifies atrazine in group III for its toxicity; however, its potential for contaminating groundwater makes it extremely important [16]. Other types of industrial pesticide for grain aphid prevention are domestic or foreign formulations of oxydemeton-methyl and thiomton (ekatin) [17]. The re leant research results demonstrated that confidor, pirimicarb, and foreign oxydemeton-methyl had been the most effective poisons against common wheat aphid. Furthermore, the foreign formulations of oxydemeton-methyl and thiomton performed better than the Iranian formulations [18, 19]. Other products with INSO approval in the Iranian pesticide market are the following: bromopropylate, permethrin, tetradifon, deltamethrin, dichlorvos, dimethoate famoxadone, pentazocine phenoprotein, carbaryl, chlorpyrifos, chlorothalonil, malathion, and metalaxyl [20].

Methods

Literature Search strategy and selection criteria

In this study, various databases including Web of Science, Pub Med, Scopus, ISC, SID were searched considering the pesticide keyword and its effect on the environment, water resources, agriculture, and health. 428 articles were obtained in the initial review, which 76 articles were deleted due to insufficient relevance to the research issue. Then, by evaluating the abstracts, another 137 articles were removed due to duplicate topics. Finally, 215 articles were thoroughly evaluated based on the objectives of the study, publication date, publication validity, and geographical extent in different regions of Iran which 76 references were used to provide the review paper.

Discussion

Pesticides disintegration

Environmental considerations, toxicity, and the long half-life of pesticides have limited the number of suitable pesticides, especially in the agriculture and hygiene sectors. Therefore, one of the necessary research fields on pesticides is their resistance to disintegration [21]. The disintegration of industrial pesticides is discussable in two main dimensions: The first dimension deals with the severe storage-associated environmental and hygienic risks, as pesticides may lose efficiency before application, disqualifying them for application. Therefore, management of production and expiration dates is regarded as an essential issue worldwide [22, 23]. Upon expiration, environmental contamination with such hazardous material is irrevocable. Neglecting to properly manage pesticide storage units can lead to grave consequences for both humans and the environment.

Shahinfar et al. (2015) investigated the feasibility of reviving the expired poisons in an agricultural support services company. The study conducted the quality control tests on samples following the guidelines set by CIPAC, FAO, and pesticide producers, classifying the results based on the following factors: poison family, physical formulation, producers, production date, and geolocation of storehouse. The results indicated no significant correlation between the age and the disintegration percentage of pesticides. The Iranian and Indian/Chinese formulations respectively represented disintegration percentages (DP) of 45% and 58%. Also, the DP of liquid formulations' was 55%, while the solid formulations showed a 29% DP. Furthermore, the study detected no statistical significance between the four climates of storehouses, DP, and shelf life of pesticides [23-25].

Pesticides' resistance to disintegration, on the other hand, though, results in even more critical problems. Therefore, environmental health specialists believe the dispersion of pesticide content in agricultural products, the food industry, water resources, and the environment is a pivotal issue. The disintegration amount differs based on age, formulation, quality control indexes (QCI), and the manufacturer. The study results by Shahinfar et al. (2015) demonstrated a non-significant correlation between the production date and DP. Moreover, domestic formulations' shelf life was higher in comparison with the Indian or Chinese formulations.

Preventing the expansion of pesticides in terms of hygiene and removing them from the environment and the food production cycle are fundamental issues. Hence, this study investigates the associated risks of this contaminant for each of the target sources. Furthermore, the study assesses the methods for the disintegration and reduction of pesticides and alternatives. This study's findings are based on reviewing the literature in the form of journals and authentic national (in Iran) and international conferences.

Pesticide and agriculture

Research reports the observance of pesticide residues in 80% of fresh greenhouse vegetables. However, the observed amounts were below the advised critical limit [26-28]. Hadian & Azizi (2006), in a descriptive research study concerning thirty samples, including cucumbers, tomatoes, cabbages, and lettuce, investigated the residues of 117 types of pesticides in the central fruits and vegetable market in Tehran. Among the 30 samples studied, 53% represented a diversity of pesticide residues, which were far below the Codex maximum level (ML) set in Codex Alimentarius and the EU. Moreover, the study did not detect DDT, HCG-g, or other forbidden poison residues in the samples [29].

In a relevant case study, Yazdanpak et al. (2019) examined the residues of imidacloprid, primacarb, oxydemeton-methyl, diazinon, and acetamiprid, which are the most used poisons in Iranian greenhouse farming, on tomatoes. The results indicated that pesticide residues began to descend close to the pre-harvest interval PHI. Furthermore, the GC-MS measurement of residues on the greenhouse products indicated that one-third of the samples represented forbidden amounts of dichlorvos and chlorpyrifos residues based on the limit defined by INSO [20, 30].

Pesticides and food industries

Due to potential toxicity, pesticide residues in agricultural products are severe health risks, resulting in unfavorable consequences, such as cancer, negative impacts on human reproduction, and nervous and immune systems. One of the main plans of management programs is to reduce the pesticide residue contaminations in the environment and food products. Food production processes significantly impact pesticide residues and food safety [31-33].

In a relevant study, Koohi et al., during 2009-2010, investigated the residues of organochlorine pesticides (OCP), such as aldrin, dieldrin, endosulfan, and dichlorodiphenyltrichloroethane (DDT) in the dairy products samples (cow milk, cheese, cream, and butter) collected from Tabriz. Even though the analysis represented that most samples contained OCP residue levels below the MRLs, aldrin and dieldrin residue levels particularly exceeded the permissible levels in some cow milk and butter samples, respectively, which can be a health risk factor. That study reflected the necessity of reducing the use of OCPs in Tabriz in the future [32].

Since the food preparation process plays a highly significant role in the pesticide residue amounts, Nazemi et al. (2016) evaluated the impact of storage conditions and the use of different disinfectants on dichlorvos residues in tomatoes [34]. They harvest the tomatoes 24 hours after the application of dichlorvos to assess its concentration. The first group of samples was stored at room temperature or in the refrigerator for ten days and rinsed with water for 20 min. Then, dichlorvos concentration changes were recorded every two days. The samples in the second group were divided into four batches. They were respectively floated in the water, 1% sodium chloride, 2% acetic acid, and 3% sodium bicarbonate solutions in periods of 10, 20, and 30 minutes. The study then used an ECD-equipped gas chromatography device to evaluate the treatment effects. The results indicated that dichlorvos residues decreased during the treatment, declining below the MRLs at room and refrigerator temperature after respectively 8 and 10 days. A thirty-minute flotation in the water, sodium chloride, acetic acid, and sodium bicarbonate respectively resulted in a 36%, 35%, 15%, and 93% decrease in dichlorvos residues. Hence, based on time and concentration factors, sodium bicarbonate solution and the acetic acid solution respectively represented the highest and lowest dichlorvos eliminating effect [34].

Yazdanpak et al. (2020) found that rinsing, peeling, and lab refrigerating is easy and effective methods for reducing and even eliminating the pesticide residues in raw agricultural products, such as greenhouse products with domestic or commercial applications. They identified peeling as the most effective technique for eliminating pesticide residues. In the comparison based on the application of four types of pesticides, the peeled and not peeled samples showed a significant difference in the residues levels, with the rinsing method ranking the second effective technique. The impact of rinsing with water depends on the quality of rinsing, types of pesticides, and the environmental indexes [33].

Pesticides in the environment

As important tools for the world's increasing population's food security, pesticides have enjoyed incredible development and extensive application. However, the excessive application has turned them into severe risks for the environment [35]. Lagoons as vast ecosystems provide valuable ecological services. Environmental pollution, especially the runoffs contaminated with pesticides, should be considered for the conservation of lagoons since increased agricultural activities in the vicinity of lagoons next to pesticide application (PA) lead to widespread lagoon contamination. From an environmental perspective, compounds with high stability and lipophilicity accumulate in the food chain of living species. Consumption of aquatics, especially fish is one of the pathways of such contaminants into the human body. Moreover, the fish are important indicators for evaluating OCPs residues in aquatic environments [36].

Karimi (2015) conducted a research study to propose a realistic approach to perform ERA of pesticides in the Shadegan Lagoon, Iran [37]. The study calculated the RQ by determining water concentration and the TRV of five pesticides, including DDT, aldrin, dieldrin, lindane, ametrine in the Shadegan Lagoon in 2011. The RQ calculation results indicated higher risks for aquatic insects than other phytoplanktons, zooplanktons invertebrates, insects, and the fish, hence the high risk for lagoons' ecosystem. The study suggested that environmental measures should be considered for reducing the risk factor in this lagoon.

Anzali Lagoon is Iran's other important aquatic ecosystem located in the south of the Caspian Sea. It is the home to fishes, aquatics, and birds with valuable ecological and economic importance. One of the contaminants in this lagoon is the range of bio-compounds with high stability. Dispersing such materials into the environment is identified as a global contamination issue, as they can accumulate in animals and humans' bodies due to their high lipophilicity and stability and spread through the food chain [38].

Surface and underground water resources

The contamination of water resources with pesticides is an environmental issue, which is an increasing phenomenon given the increasing growth of agriculture in the majority of provinces in Iran, jeopardizing freshwater resources. Research shows that pesticide residues in water resources are directly associated with pesticide application in such regions; if pesticide application is left uncontrolled, these disintegration-resistant contaminants will seriously threaten public health [39].

Khodadadi et al. (2009) investigated the effect of pesticide application on freshwater resources, aiming to determine the residue concentrations of halogenated Chlorpyrifos) and non-halogenated Diazinon, and Carbamate (carbaryl) organophosphate pesticides in the water supply sources in (city of) Hamedan. They collected 126 samples from seven surface and underground freshwater sources during a year and prepared them using the SPE method. Then, the study used HPLC and GC/MS/MS devices for sample analysis. The results indicated that carbaryl and Diazinon respectively represented the highest concentration in spring (May) and Fall (September). Also, the pesticides in question represented the lowest concentration in winter.

Dargahi et al. (2018) studied the residues of a group of organophosphate pesticides, including diazinon, malathion, chlorpyrifos, glyphosate in the surface and underground freshwater sources in (province of) Kermanshah. The collected samples from 50 water source stations geographically dispersed in Kermanshah (north, south, east, west). The results indicated no residues in any sources, including springs or ducts and glyphosate, represented the lowest residues. Besides, the total residues of malathion and glyphosate were below the MRLs set by the EU. The overall results indicated that given the organophosphate pesticides' current concentrations in the wells in the region exceeding the MRLs set by the EU, it would seriously put the public health at risk to neglect to control the pesticide application and regularly monitoring water resources [40].

These chemical residues not only negatively impact consumer's experience, but they also impair the quality of life in the ecosystem for aquatics or even destroy them. The sample collection started in May and …. to investigate the association between the diazinon residues in the Tajan River and the agricultural activities in the river vicinity. The study used HPLC to investigate the diazinon residues in the prepared samples. The maximum recorded concentration of diazinon equaled 47 µg/l in May at the third water source station. Results analysis indicated that diazinon concentration increased with the beginning of the farming activities, especially rice cultivation, fluctuating during summer based on the application time. Given the one-hour average concentration limit set by the EU is 0.17 µg/l, which should not be exceeded more than once per three years (the acute toxicity criteria), the study concluded that diazinon concentration in the Tajan River increased under the effect of increasing agricultural activities, putting the ecosystem at high risks [41].

Kalachian et al. (2011) investigated the lindane-absorption potential of the sediments and the association between sediments' physical and chemical properties and lindane absorption in the Karun River. They collected samples in dry and wet seasons from the fifth bridge on the river in Ahvaz and Khorramshahr. The results indicated that salinity and the sediment amount increased along the river from Ahvaz to Khorramshahr. The sediments at Darkhovin contained the highest organic matter (2.45%) and 30.8% clay content, while the sediments around the fifth bridge represented the lowest organic matter 0.49% and clay content (2.1%). The value of K_f (Freundlich adsorption isotherm) for the sediments in Darkhovin was the highest (196 mg/kg) and the lowest (82 mg/kg) for the fifth bridge in Ahvaz. Besides, the sediments in Darkhovin and the fifth bridge in Ahvaz respectably represented the highest (340 mg/kg) and lowest (140 mg/kg) value of b (Langmuir adsorption isotherm). Moreover, the study detected a significant association between lindane absorption levels and organic matter and sediments [42].

Pesticides and hygiene

Humans are exposed to the poisonous content of the pesticides in various ways following the application and pesticides' remaining in the environment. Pesticides do not function selectively, therefore, they also affect other creatures like humans and the target pests [43].

In the last two decades, biologists have been focusing on chemicals synthesized in laboratories and manufactories that, upon entering the body, can function like attenuated hormones causing the endocrine glands to malfunction. Importantly, some associate the exposure to such chemicals with many of the disorders in animals, such as population decline, eggshell thinning, morphological discrepancies, higher mortality as well as the increased infertility rates and reproductive disorders, decline in total sperm count, and cognitive disorders in humans related to intelligence and learning [44-49].

Today, pesticide application has been widely challenged in hygienic concerns in developing and developed countries. Many studies have confirmed the direct relation between PA and hormonal diseases and the subsequent side effects. The study results by Ebrahimi & Manian (2007) in (province of) Fars, Iran, represented that more than 1.5 million liters of 86 types of pesticides have been applied to land 34 of which were carcinogenic. They classified at least 30 types of pesticides as hormonal contaminants. Some poisons were found to selectively cause specific hormones to malfunction [50].

Since pesticides are mostly stored at home and women mostly apply them, women and even children are more at risk at home. Hence, in a relevant study, they studied the awareness, knowledge, and performance of women regarding health risks, appropriate storing procedures, and pesticide application. The statistical population consisted of 465 women from (city of) Yazd who were mostly educated, having a bachelor's degree and above. The results indicated that about 17% of women received the required training regarding the storage procedures and potential health risks from television [51-54]. Also, more than 23% of women relied on the instructions on the packaging of pesticides as their main source of information. Therefore, since the majority of consumers are willing to decrease the PA-associated risks, it is possible to improve their performance through awareness-raising campaigns [55] optimally.

Safety against pesticides

Respiratory exposure to pesticides is another adverse effect of their application. Two studies have investigated such negative effects on the respiratory exposure to pesticides in a population of workers and farmers, including [56].

Based on the agricultural product and the efficacy, different regions require specific pesticides. For instance, in Rafsanjan and Savojbolagh county, in Iran, more than 95% of pesticides are organophosphates. Besides, about 68% of farmers in the study did not use any protective gear form, and only 25% of farmers claimed they grasped the packaging instructions. Also, 55% left the containers of pesticides in the environment after application, and only 27% incinerated or buried the containers [57]. To study the influential factors in farmers' safety behaviors regarding wearing protective gear when using pesticides, a statistical population consisting of 322 wheat farmers in central Zanjan was investigated. The results indicated that farmers' behavior concerning the use of protective gear was identified as low (unsafe and potentially unsafe). Moreover, the experimental results indicated that the six constructs of HBM, including perceived susceptibility, perceived severity, perceived benefits to action, perceived barriers to action, self-efficacy, and cues to action [58].

HBM is one of the most extensively applied models for studying behavior to prevent and control diseases. Ghanbari et al. (2018) in their study, analyzed the HBM constructs in the safety behaviors of farmers when using pesticides. The statistical population included the entire farmers in Khoramabad. They determined 375 farmers for the population size population using the Krejcie and Morgan table and used questionnaires for data collection [59]. The results indicated that the variables, including awareness, perceived susceptibility, perceived barriers affected farmers' behaviors, with perceived barriers and awareness having the highest impact. Therefore, emphasizing the reduction of barriers and raising awareness, that study suggested HBM-based measures to improve farmers' safety behaviors [60-62].

Pesticide reduction and disintegration

Various physical and chemical methods have been proposed for pesticide elimination for land and aquatic ecosystems; however, some of them are highly costly and yield other poisonous byproducts [63]. Regarding the expansion of the science of interaction between humans and nature, biological treatment gained much importance. Biological treatment is a process in which microorganisms are employed for breaking down the contaminants in the environment. Bioremediation is an economically and environmentally optimal method for removing persistent contaminants. Today, the use of indigenous or genetically-engineered microorganisms in the treatment of contaminated environments is widely increasing. The determination of soil properties and ecotoxicology to identify the abilities of soil innate microorganisms is essential for the effective use of this green technology [16].

Diazinon-degrading bacteria are present in the contaminated agronomic and industrial areas. Hence, these bacteria and bioregenerative processes are expected to reduce the adverse environmental effects of pesticides. Moreover, after field studying and determining the formulations, it is expected to use such bacteria strains for bioremediation [11].

Molecular imprinting is one of the modern techniques for synthesizing absorbing products for the extraction of pesticides. Mansoori et al. (2018) investigated the synthesis and performance of molecularly imprinted films produced using the electrospinning method to extract mecoprop. The results rendered this method successful for cleaning up aquatic environments such as mineral water resources and wells [64].

Accordingly, Karami et al. (2019) investigated malathion and diazinon residues in the olive washing and fermentation processes. The statistical results showed after the washing and debittering processes, the malathion and diazinon residues decreased by 74% and 93%, respectively, while they respectively decreased by 63% and 69% after 20 days of fermentation. After fermentation and near the end of the process, the malathion and diazinon residues showed a 90% and 98% decrease, respectively. Broadly, the statistical results indicated that the fermentation process significantly reduced malathion residues while non-significantly impacting diazinon residues. Indeed, the reducing impact of fermentation is also a function of poison type, fermentation time, and different environmental conditions.

Bazrafshan et al. (2017) investigated the optimization of the electrocoagulation process in the removal of diazinon residues from aquatic environments using RSM. In that study, they designed thirty experiment stages to examine the effects of some independent variables, including diazinon residue (10-100 mg/l), applied voltage (20- (20-40 W), reaction time (RT) (10-16 min), and the solution pH (3-10) on diazinon elimination efficiency. Conditions were optimized using

RSM, and model analysis was conducted using ANOVA. The proposed model was significant at a 95% confidence level. The results indicated that diazinon elimination efficiency was a function of primary concentration changes, voltage, and RT. The determined diazinon elimination efficiency in an optimal condition (a residue of 100 mg/l and a voltage of 20W) was 85%. Therefore, the electrocoagulation process is an effective method for eliminating diazinon from water solutions, and the optimized experiment design successfully removed diazinon residues, allowing for an optimal decontamination condition by the minimum number of experiments [65].

The presence of resistant biological contaminants, such as pesticides in the surface, underground and freshwater resources besides the inability of current water treatment procedures to eliminate such contaminants have led to the emergence of Advanced oxidation processes (AOPs). Hence, the introduction of AOPs is another mechanism for removing poisons, which has grabbed the attention of researchers. The results indicate that an increase in pH and contact time and a decrease in poison concentration increase elimination efficiency. Using AOP combined with UV/O3 for the removal of two families of pesticides, including halogenated (chlorpyrifos) and non-halogenated (diazinon) organophosphorus poisons represented an 80% efficiency, which reaches 90% for a carbamate poison (carbaryl). As a result, this method is suggested as a useful way of eliminating the poisons from the aquatic environments in the study [66].

A relevant study with a similar design was the work of Dehghani and Fadaei (2015), which aimed at using zinc oxide nanoparticles in conjunction with UV for pesticide removal from water sources. The process was conducted in a batch reactor in two diazinon concentrations (100, 500 mg/l) in the presence of zinc oxide nanoparticles with diameters ranging 6-12 nm, with three various concentrations (50, 100, and 150 mg/l), using a 150-W UV medium-pressure lamp in five different time variables and pH levels of (9, 7, and 3). The highest elimination efficiency was recorded under a pH of 3, while the lowest efficiency was observed at a pH of 9. Also, the nanoparticles showed the highest elimination efficiency at a concentration of 100 mg/l. Therefore, nano-photocatalytic methods are also identifiable as clean, environmental-friendly processes usable on large scales [67].

Domestic or industrial food processing is an almost suitable approach for dealing with unhygienic contaminated food [68]. Attempting to study the impacts of commercial processing on pesticide residues in food material, food industry researchers have demonstrated that operations like peeling, washing, blanching, essence extraction, and thermal processing can reduce the residue levels in agricultural products, like tomatoes, broccoli, green beans, spinach, and so forth.

The first step in the food and agriculture industries for the residue reduction is to determine their levels so as to decide less disadvantageous executive plans for combating the carriers and pesticides based on more realistic judgments and a richer understanding of these chemicals' role in the food cycle [69, 70]. As mentioned above, OPs are widely used in the agricultural sector, a significant portion of which is left untreated in the environment, resulting in unfavorable effects on the ecosystems, wildlife, and humans. Nevertheless, given the increasing trend in salinity in the agricultural sector, especially in drainage water, the need to decontaminate and reuse these water sources due to water shortage, bioremediation is considered an effective and environmentally-friendly method usable for desalination. The role of degrading bacteria in pesticide elimination from different environments further highlights this issue's importance [12].

A relevant study used the targeted enrichment technique to separate halophilic bacteria capable of disintegrating chlorpyrifos (an OP) and identified the superior strain in terms of the highest growth rate and tolerance against pesticide content. They used a GC/MS device to analyze the selected strain's disintegrating ability, and the strain was identified using the molecular method. The study investigated the optimal growth condition (to demonstrate the denigration condition better) by examining the impacts of temperature, acidity, salinity, and chlorpyrifos concentration on bacterial growth in pesticide presence (the only carbon source). The results indicated that thanks to their adaptability to saline conditions, halophilic bacteria are suitable options for eliminating OPs in contaminated saline environments [71].

A different, softer way for reducing pesticides is raising consumers' knowledge about dealing with these contaminants. Various research studies have found that improving knowledge and awareness has proved significantly effective in the combat against pesticides [72-74].

Alternatives to Pesticides

Today, various studies are attempting to introduce alternatives for chemical pesticides. These alternatives include physical (environment optimization, installment of mesh in the greenhouse, and so on), biologic (using natural enemies of pests or bacteria), and genetic methods [75-78].

In recent decades, nanotechnology has enjoyed a wild expansion in various fields, including the aerospace industry, different industries, such as military, food, chemical, pharmaceutical, medical, and pesticide manufacturing. In a simple comparison, nano pesticides are more economical, hygienic, and medically crucial than traditional industrial pesticides. With higher efficacy in comparison with industrial pesticides, nano pesticides are more also useful for fighting arthropod pests in agriculture and the carriers of severe diseases like malaria. Nowadays, nanopesticides are produced using diverse methods. Since nanopesticides are critical for public hygiene, it is essential to identify new synthesis methods [79]. As mentioned earlier, environmental controlling procedures can significantly reduce the population of pests by optimizing the environment and causing undesirable conditions for pests' reproduction and growth [80, 81].

Using environmental controlling methods, it is possible to keep the environment clean and safe to ensure public health, which is one of health organizations' goals [82]. Moreover, as proved in many cases, the use of low-risk, biological pesticides, PHI observance, and responsible application in compliance with environmental and hygienic standards will alleviate their negative effect, highlighting their advantages.

Conclusion

Regarding the pandemic population growth, the limited sources in the agricultural sector, and the urgent need for increasing the production of agronomic products, the need for combating pests logically and responsibly with an emphasis on protecting the lives of farmers and the public is felt more prominent than ever. This paper investigates the effects of pesticides on the hygiene, environment, agriculture, the food industry, and water resources quality. It reviews the different methods for confronting the disadvantages of pests and pesticide application.

Relevant studies indicate that, in Iran, the excessive use of pesticides is based on different reasons, including farmers' unawareness, availability of cheap pesticides, and unauthorized stores; therefore, the management process for controlling pesticide use requires intervention for quality improvement. Pesticides' resistance as a result of increased dosage can also lead to aggravating environmental contaminations. Pesticide application has immensely unfavorable repercussions for the environment, including enhanced poison-resistance in arthropods that, in some cases, has caused the whole pest (including carriers) control operation to fail, resulting in major economic loss and hygienic damages [83].

Various factors are effective in reducing the negative impacts of pesticides: development of organic agriculture, raising supervision on the imports of poisons and pesticides, equipping laboratories with state-of-the-art related science in cooperation with the private sector, training farmers to improve their knowledge, revision and then execution of current regulations, and developing and applying an identification system for products as well as strengthening supervision. Although these suggestions are convergent and consistent, for maximizing the effect of these policies, a combined approach including all the suggestions is advisable [84].

The correct selection of a suitable pesticide, dosage, and time of application are among other ways for combating pesticide residue expansion in the environment [85-87]. The importance of using vegetables every day and the adverse effects of pesticide use on public hygiene emphasize regularly checking the residues of such chemicals in vegetables [88]. Therefore, this study suggests that the related supervisory health organizations formulate the required pesticide control plans.

The practical methods proposed for ensuring the removal of pesticide residue from greenhouse products include soaking in an alkaline solution complying with the PHI and floatation for a needed amount of time [32, 89].

For preventing the side effects associated with pesticides, consumers need to receive proper training courses regarding the introduction of poisons and their applications, short-term and long-term side effects, effective use of the protective gear, the essential steps after the application of poison under the supervision of pre-determined units with proficient experts. These training pieces should be produced in simple and straightforward Farsi, and ideally local languages and dialects. Employers and authorities are responsible for supplying personal protective gear and provide farmers with the pieces of training and briefings required concerning urgencies and the proper and hygienic procedures for the incineration and burial of pesticide containers [56].

Author Contributions

Majid Khayatnezhad and Fatemeh Nasehi conducted, planned, analyzed the data, wrote manuscript and interpreted the results and involved in manuscript preparation.

Competing Interest

The authors declare that they have no competing interests.

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